E7.3-1 1 0.1 3
CR-133806

SIXTH PROGRESS REPORT

on

CALIBRATION AND EVALUATION OF SKYLAB ALTIMETRY FOR GEODETIC DETERMINATION OF THE GEOID (Contract NAS9-13276, EPN 440), August 1 to August 31, 1973

to

NASA Johnson Space Center
Principal Investigation Management Office
Houston, Texas 77058

from

BATTELLE
Columbus Laboratories

September 17, 1973

A. G. Mourad - Principal Investigator, D. M. Fubara - Co-Investigator
Z. H. Byrns, Code TF6 - NASA/JSC Technical Monitor

(E73-11013) CALIBRATION AND EVALUATION OF SKYLAB ALTIMETRY FOR GEODETIC DETERMINATION OF THE GEOID Progress Report, 1-31 Aug. 1973 (Battelle Columbus Labs., Ohio.) 9 p HC $3.00 CSCL 08E G3/13

N73-31318

Unclas
01013

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

SIXTH PROGRESS REPORT

on

CALIBRATION AND EVALUATION OF SKYLAB ALTIMETRY FOR GEODETIC DETERMINATION OF THE GEOID (Contract NAS9-13276, EPN 440), August 1 to August 31, 1973

to

NASA Johnson Space Center
Principal Investigation Management Office
Houston, Texas 77058

from

BATTELLE
Columbus Laboratories

A. G. Mourad - Principal Investigator, D. M. Fubara - Co-Investigator
Z. H. Byrns, Code TF6 - NASA/JSC Technical Monitor

September 17, 1973

## PROGRESS

During this period, we concentrated our efforts on resolving the problem encountered in the transformation of coordinates from SKYBET data which was reported in the last progress report. Two of the four microfiches received from JSC (References 1 and 2) and the SKYBET Parameter Formulation Document (Reference 3) were intensely studied. These reports contain important information critical to the success of the analytical data handling in this project. Using the information from References 1-3, a new computer program was written for conversion of SKYBET data to other required geodetic parameters. The above problem has been resolved except in the computation of ellipsoidal heights of the satellite. The unresolved portion of the problem is the discrepancy of about 11 to 16 meters between Battelle results and JSC SKYBET computations.

We also initiated work on (a) analysis of geoidal groundtruth required for calibration and validation, and (b) development of a program to handle the data from subsequent Skylab missions using sequential least squares solution update technique to economize computer time and storage requirements.

The Principal Investigator, at no cost to this project, participated in the GEOP Research Conference on the Geoid and Ocean Surface. A summary report on this conference is included in Appendix A. The main conclusions that can be drawn from this conference which are of relevance to this contract include,

(1) the apparent lack of adequate interaction between planners, equipment designers and discipline users.

(2) the still unresolved controversy on the difference between oceanographic and geodetic determination of mean sea level (MSL). There appears to be a lack of concerted effort to resolve such differences by systematic research; and

(3) the need for adequate geodetic ground truth in support of satellite altimetery at the sub-meter level of accuracy.

Several documents were received and reviewed. These are listed in Appendix B.

## PROBLEMS

The major problem is the delay in the receipt of Skylab S-193B data. This has seriously affected our "milestone plan" and work schedule. The reported expenditure for the period reflects the reduced effort imposed by the data delay. This condition is not compatible with optimum utilization of resources.

The unresolved problem in the computation of ellipsoidal heights from SKYBET data could be due to (1) the ellipsoidal parameters used and/or (2) the mathematical formulation used in the computation. We used the following ellipsoidal parameters as stipulated in Reference 3:

Semi-major axis = a = 6378165.0 m

Semi minor axis = b = 0.9966486077 a

which represents

Flattening = 1/298.38

The mathematical formulation used is a standard geodetic technique. This was slightly different from the formulations as stated in "Earth Resources Experiments Package (EREP) Pointing Display Processor", Reference 2.

An example of the differences between our computations and JSC result of SKYBET data are shown in Appendix C.

## RECOMMENDATIONS

(1) The delivery of Skylab (SL/2) S-193 B data should be expedited.

(2) There should be interaction and interface between (a) the group reducing the S-193B data to metric ranges and (b) discipline Scientists and user group. This is necessary because the process of assigning correct scale when converting the radar returns to linear ranges involves geodetic concepts.

(3) The differences between Battelle coordinate transformation results and those of JSC should be brought to the attention of the Data Processing Branch responsible for generating SKYBET.

## NEXT PERIOD

We expect to receive the required SL/2 altimeter data to perform the tasks of this project. The ground truth geoidal analysis and the development of the sequential solution update program that were initiated in this period, as reported earlier, will be continued in the next period.

## TRAVEL

The Principal Investigator attended the GEOP Research Conference on the Geoid and Ocean Surface in Boulder, Colorado, under a separate NASA contract. To implement recommendation (2) above, we plan to visit and discuss with GE and NASA Wallops the reduction of Skylab radar data to metric ranges.

## RESULTS

See Appendix C.

## SUMMARY OUTLINE

The delay in receipt of the Skylab altimeter ranges is causing delays in our milestone plan.

## REFERENCES


1. "RTCC Requirements for Analytic Determination of Coordinate Transformations for the Earth and Moon for Skylab", MSC Internal Note No. 70-FM-224 Mathematical Physics Branch, Mission Planning and Analysis Division, January 26, 1971.

2. "Earth Resources Experiments Package (EREP) Pointing Display Processor", MSC Internal Note No. 71-FM-430, Mission Integration Branch of Mission Planning and Analysis Division, January 6, 1972.

3. "SKYBET Parameter Formulation Document", Change 1, Data Processing Branch, Flight Support Division, NASA/MSC, February 8, 1973.

APPENDIX-A

Summary Report

on the

Fourth GEOP Research Conference: The Geoid and Ocean Surface held on August 16-17, at the University of Colorado, Boulder, Colorado

The GEOP Research Conference dealt with important topics of interest to the GEOS-C and the Earth and Ocean Physics Programs. The topics that were discussed included;

(1) Reference Surfaces and Height Systems: Ocean and Earth
(2) Departures of Sea Surface from the Geoid
(3) Instrumentation and Data Acquisition, and
(4) Analysis Techniques for Determining the Geoid and Ocean Surface Topography.

The various methods used in determination of the geoid were reviewed along with the associated problems and limitations of such methods. There were differences of opinion as to the accuracy of existing geoids (particularly at sea) that could be used for ground truth in satellite altimetry. Agreements appeared possible on the availability of ±5 meter regional geoid in certain areas of the ocean. Obtaining a sub-meter, or ultimately 10-cm geoid, however, will be an extremely complicated problem in practice. The question of a 10-cm geoid and the need for it arose. Some of the oceanographers felt that it would be nice to have it, but apparently would not know how to use it. Others felt they can use it. It is clear that the user requirements must be investigated and precisely defined.

It was recommended that the best possible geoid should be established in a limited region such as the Bermuda-Wallops-Bahamas triangle which is to be used for GEOS-C. The best method identified for establishing such an accurate geoid (±1 meter or better) involves use of astrogravimetric techniques in conjunction with ocean-bottom geodetic control.

The problems associated with various level and reference surfaces that are used in geodesy and oceanography were brought out and discussed. Unfortunately, there is no simple way of presenting such problems without over simplification. The details involved tend to confuse the non-specialists. Accordingly, the results of the geodetic determination of mean sea level by spirit leveling still differed from those determined by oceanographic techniques. Geodesists felt that it is the oceanographic concept of equipotential reference surface that may be incorrect while the oceanographers tend to believe that the source of errors could be in geodetic leveling. The results of releveling of certain loops on the U.S. East Coast by NOAA resulted in a disagreement of only 2-cm standard error from the old network. This certainly can not explain the apparent difference of 60-cm in mean sea level on the East Coast sloping in opposite direction to that of the oceanographic slope determination. In further defense of the geodetic leveling approach, it was suggested that the problem of oceanographic determination of MSL may be due to the fact that the reference surface which the oceanographer use is a pressure surface (considered as an equipotential surface) and is not necessarily equivalent to the earth's equipotential surface used by geodesists.

There were some discussions related to determining mean sea level by taking the average of annual sea level and also measuring the instantaneous mean sea level by whatever means available. In summary, the two basic unresolved problems are (1) the difference between geodetic and oceanographic determination of mean sea level, (2) definition of an accurate geoid for ground truth to satisfy most groups.

In regard to instrumentation and techniques, it was concluded that it will be possible to eventually get accurate instrumentation for obtaining a 10-cm geoid using compressed radar pulse technique. There were several presentations on various theoretical and statistical analysis techniques that are aimed at obtaining better accuracy out of altimetry data.

Satellite to satellite tracking was recommended as the ultimate in obtaining high precision satellite orbits. Station coordinate errors from short arc satellite orbits were reported to be about ±2 meters and those from long arc are as high as 7-8 meters.

The preliminary results of a track from Skylab altimetry were shown to agree very good with an existing geoidal map obtained from surface gravity data.

## APPENDIX B

List of Documents and Data received during August, 1973.

(1) Skylab II, S190A, 461682-4-PI, 70 mm Trans., 1 ea. Pos, Mag. 10, Frames 270/273 and Mag. 16, Frames 171/185.

(2) W/O #5147, Skylab II, S190A, 461636-4-PI, 70 mm Trans., 1 ea. Pos., Mag. 10, Frames 176/190.

(3) Skylab II S193B Stripcharts - Setups 1-3

| DDC ACC. NO. | PASS NO. | REQ. NO. | START | STOP |
|---|---|---|---|---|
| 32-04029-31 | 07 | 1139 | 161:14:27:50 - | 161:14:30:51 |
| 32-04032-34 | 07 | 1140 | 161:14:31:53 - | 161:14:35:10 |
| 32-04035-37 | 09 | 1141 | 163:13:01:30 - | 163:13:04:55 |
| 32-04038-40 | 04 | 1142 | 155:17:11:00 - | 155:17:14:50 |
| 32-04041-43 | 06 | 1138 | 160:15:15:14 - | 160:15:19:10 |

(4) Skylab II/EREP Data Books

| DDC ACCESSION NO. | DDC DPR NO. | REQUEST NO. |
|---|---|---|
| 32-05233 | 726 | S190A-0106-02-06-22-1 |
| 32-05034 | 613 | S190B-0087-02-07-32-1 |
| 32-05130 | 727 | S190A-0107-02-09-22-1 |

(5) "Mission Requirements - Appendix B, Revision B, Earth Resources Requirements, SL-1/SL-2, SL-3 and SL-4", I-MRD-001, NASA/JSC, July, 1973.

(6) PHO-TR523, Rev. A, Ch.1, from Philco Ford Co., August 2, 1973.

(7) Skylab EREP Field Data Pack, SL-3 Mission Supplement, dated July 23, 1973.

# APPENDIX C

The table below shows an example of results of coordinate transformation of SKYBET data to geodetic latitude, longitude and heights. The SKYBET data were taken from "EREP Postpass Summary Report", EREP Pass No. 6; GT-19, Rev 374/5 on GMT 160:15:07:0.00 to 160:15: 16:0.00. Geodetic parameters used were

Semi-major axis = 6,378,165.0 m.

Flattening = 1/298.38

Earth rotation rate = 0.2625161452800494 rad/hr.

TABLE C-1. GEODETIC COORDINATES DERIVED FROM SKYBET ECT COORDINATES

| Source of Computation | Geodetic Latitude in deg. | Geodetic Longitude in deg. | Geodetic Height in m |
|---|---|---|---|
| JSC | 42.14923 | -97.79683 | 440,236.57 |
| Battelle | 42.14918 | -97.79684 | 440,220.82 |
| JSC | 40.11883 | -93.69366 | 440,274.17 |
| Battelle | 40.11878 | -93.69366 | 440,261.48 |
| JSC | 37.93423 | -89.85124 | 440,275.88 |
| Battelle | 37.93417 | -89.85125 | 440,262.06 |
| JSC | 35.61528 | -86.25113 | 440,251.22 |
| Battelle | 35.61525 | -86.25112 | 440,237.20 |
| JSC | 33.17984 | -82.87235 | 440,208.50 |
| Battelle | 33.17981 | -82.87235 | 440,195.82 |
| JSC | 30.64387 | -79.69291 | 440,158.94 |
| Battelle | 30.64384 | -79.69290 | 440,147.01 |
| JSC | 28.02148 | -76.69080 | 440,112.79 |
| Battelle | 28.02145 | -76.69080 | 440,101.75 |
| JSC | 25.32520 | -73.84477 | 440,079.59 |
| Battelle | 25.32517 | -73.84476 | 440,066.33 |
| JSC | 22.56610 | -71.13454 | 440,068.85 |
| Battelle | 22.56608 | -71.13454 | 440,055.81 |
| JSC | 19.75406 | -68.54100 | 440,089.11 |
| Battelle | 19.75404 | -68.54100 | 440,076.77 |